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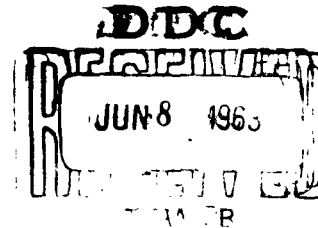
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HIGH ENERGY RATE EXTRUSION PROGRAM

INTERIM TECHNICAL PROGRESS REPORT NO. 10
1 February 1963 to 31 May 1963

BASIC INDUSTRIES BRANCH
MANUFACTURING TECHNOLOGY LABORATORY
AERONAUTICAL SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

ASD PROJECT NO. 7-882



A series of high-velocity extrusions were made which demonstrated the reproducibility of this process for making Tee shapes 2 inches by 1 inch by .050 inches from Ti-6Al-4V, AISI 4340 and 304 stainless steel. Nominal surface finish of eleven extrusions was 80 RMS. Thickness variation on the stem and flanges was normally .002 inches to .003 inches. Radii at the intersection of the stem and flange were under .03 inches.

(Prepared under Contract AF33(600)-41948 by the Westinghouse Electric Corporation, Materials Manufacturing Division, Blairsville, Pennsylvania, J. M. Rippel)

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FOREWORD

This Interim Technical Progress Report covers the work performed under contract AF 33(600)-41948 from 1 February 1963 to 31 May 1963. It is published for technical information only and does not necessarily represent the recommendations, conclusions or approval of the Air Force.

This contract was awarded to the Westinghouse Electric Corporation and is being carried out at the Materials Manufacturing Division, Blairsville, Pennsylvania. It was administered under the technical direction of Mr. T. S. Felker, ASRCTB, Manufacturing Technology Laboratory, Wright-Patterson Air Force Base, Ohio.

Mr. J. M. Rippel of the Westinghouse Materials Manufacturing Division, was the Project Engineer. Mr. D. H. Moreno and Mr. R. L. Cook, Materials Manufacturing Division, also contributed. The operation of the Dynapak machine at the American Brake Shoe Research Laboratory is under the direction of Mr. G. Macdonald.

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ABSTRACT SUMMARY
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HIGH ENERGY RATE EXTRUSION

by

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A series of high-velocity extrusions were made which demonstrated the reproducibility of this process for making Tee shapes 2 inches by 1 inch by .050 inches from Ti-6Al-4V, AISI 4340 and 304 stainless steel. Nominal surface finish of eleven extrusions was 80 RMS. Thickness variation on the stem and flanges was normally .002 inches to .003 inches. Radii at the intersection of the stem and flange were under .03 inches.

The extrusions were made on a Dynapak high-velocity extrusion press manufactured by General Dynamics. All the materials were extruded through ceramic coated dies at a reduction ratio of 17:1. The dies were lubricated with graphite and no billet lubrication was used. Lengths obtained varied from 8 feet to 11 feet depending on the power used. The Dynapak machine is capable of producing energies of approximately 300,000 foot pounds.

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I. INTRODUCTION

The purpose of this contract is to advance the state-of-the-art of high-velocity extrusion and to determine the capabilities of the Dynapak machine when applied to the extrusion of various metals into structural shapes of the quality required for aircraft, missile and spacecraft construction.

Investigation of the process parameters will comprise the bulk of effort in determining precisely the capabilities and limitations of the machine relative to extruding the desired lengths and cross-sections. A process will be established for the extrusion of the selected materials and an analysis made of the variables of the process.

Phase I will be the evaluation of the current state-of-the-art of high-velocity extrusion.

Phase II will be the establishment of a process for extruding titanium and steel alloys, Ti-6Al-4V, AISI 4340 and 304 stainless steel, into a Tee configuration 2 inches by 1 inch by .050 inches thick and 10 feet in length. See Figure 1. In addition, these extrusions are to have a surface finish of 100 RMS and to be of aircraft quality.

Phase III will be similar to Phase II in respect to the type of work to be done but will deal with refractory metal alloys of molybdenum and columbium.

Phase IV will be the pilot production of five extrusions of each material investigated to demonstrate the reliability of the developed process and to insure consistency in the extrusions produced.

The literature survey of Phase I has been completed. Although a comprehensive survey was made, the state-of-the-art of high-velocity extrusion is new and undeveloped and few references are available. The state-of-the-art of high-velocity structural extrusion was practically non-existent.

The work required in Phase II has also been completed. Ten foot Tee extrusions of Ti-6Al-4V alloy which meet all the requirements of surface finish, tolerance and dimensions have been made. Stainless steel and AISI 4340 extrusions have also been made in lengths of 10 feet which meet all the requirements except the dimensional tolerances. The cross section is slightly reduced in a local region of the ten foot lengths. Eight foot lengths of steel can be produced meeting all the dimensional requirements and having only a .002 inch variation in thickness along the length. For existing high-velocity extrusion machines and this cross sectional area, eight feet should be considered the maximum capability for materials with the density of steel ($.3 \text{ lb/in}^3$).

Phase III and IV have not yet been started.

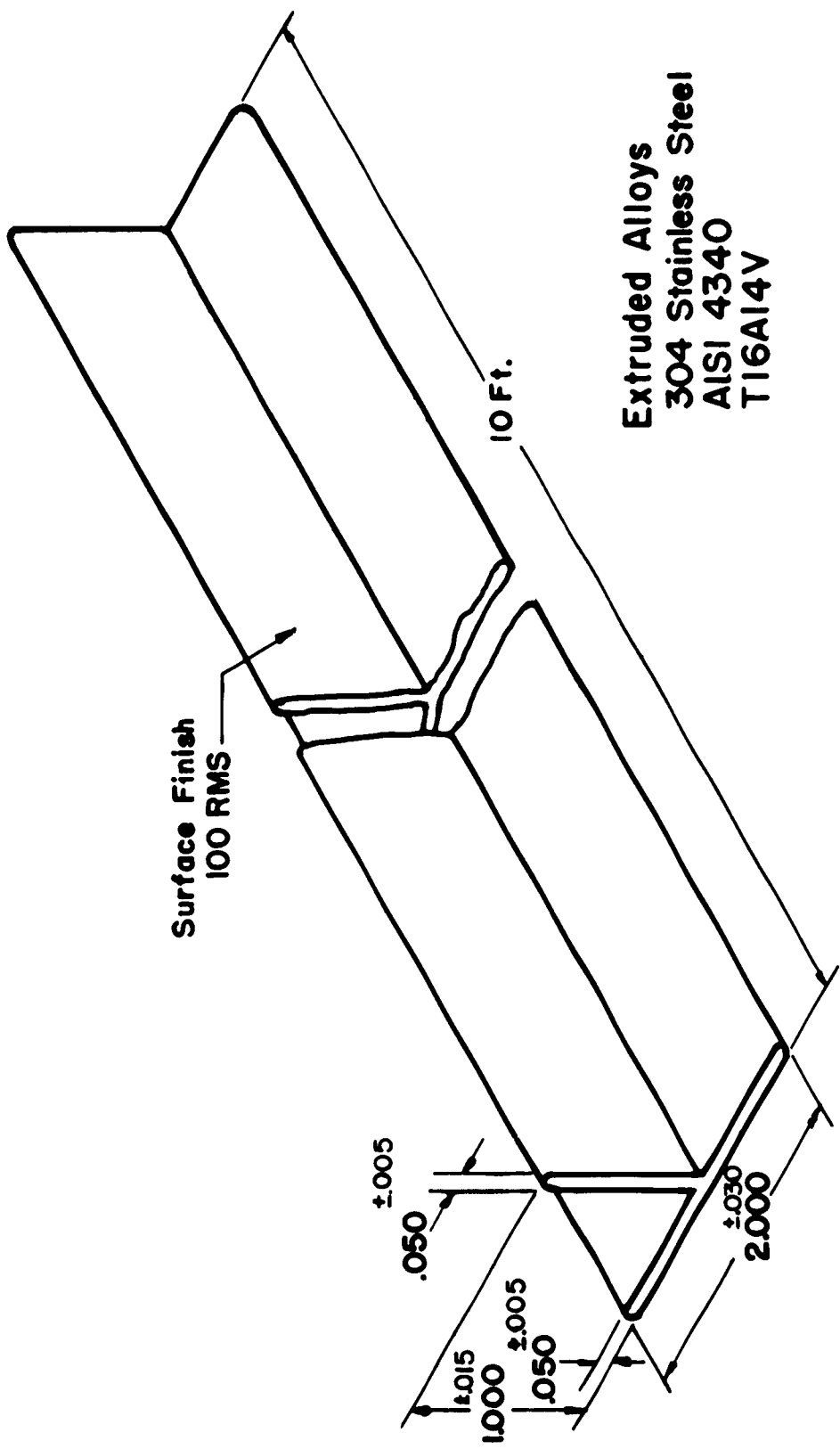


FIGURE 1 - Basic design of tee configuration used for high energy rate extrusion contract.

II. SUMMARY OF WORK IN THE PAST QUARTER

Work in the past report period demonstrated the repeatability of the high-velocity extrusion process. Long lengths and good surface were obtained previously, but not consistently one extrusion after another. In the last extrusion trials, eleven extrusions were made from the three materials, Ti-6Al-4V alloy, AISI 4340 and 304 stainless steel. All the extrusions had satisfactory surfaces and dimensional tolerances.

III. CONCLUSIONS

- A. The feasibility of consistently producing thin structural shapes by the high-velocity extrusion process has been demonstrated on Ti-6Al-4V alloy, AISI 4340 and 304 stainless steel.
- B. With properly coated and sized dies, extrusions with surface finishes of better than 100 RMS and with the required dimensions can be produced.

IV. DISCUSSION

A. Extrusion Equipment and Procedure

1. General Description

Two extrusion trials were made in the last quarter. In the first trial only four extrusions were made because the dies proved to be defective. Eleven extrusions were made in the second trial. Ti-6Al-4V, AISI 4340 and 304 stainless steel were the materials extruded and all extrusions were of the Tee configuration which has nominal dimensions of 2 inches by 1 inch by .050 inches.

An 1810 model Dynapak machine, manufactured by General Dynamics, see figure 2, was used on all extrusions. A smaller model, 1210 Dynapak, is also available and has been used in some of the previous trials. The 1810 Dynapak machine is capable of producing energies of approximately 300,000 foot pounds. On both of the last trials, energies of 200,000 foot pounds to 300,000 foot pounds were used producing extrusions from 8 feet to 11 feet long.

2. Heating Procedure

All billet heating was done in a BaCl_2 salt bath. The Ti-6Al-4V billets were heated to 1825°F and both of the steel alloys were heated to 2150°F . Soaking time was nominally 10 minutes for all materials and, after heating, billets were removed from the salt bath, inserted in the billet container and extruded in a period of 5 to 7 seconds.

3. Lubrication

All billets were heated in the BaCl_2 salt bath and were not further lubricated. The salt does provide a certain amount of lubrication. The die and container were lubricated with graphite. The graphite is mixed with alcohol and applied by spraying. The graphite appears to be very important and must be applied liberally to the die. On the ceramic-coated die, the graphite prevents metal pickup in the die land and essentially acts as an anti-seizing compound. Without the graphite, short extrusions can be made with good surfaces, but on the longer extrusions, the extruded material builds up in the die land causing deep scratches in the extrusion.

4. Tooling

The tooling for all extrusions and materials was the same. A split, three-piece, ceramic-coated die was used. In addition, a split, two-piece, preform die was placed on top of the die. This shapes the billet to a Tee configuration 2-1/2 inches by 1-1/4 inches by 1/2 inch prior to the billet's entering the ceramic-coated die. The die and preform are shown in Figures 3, 4 and 5. The preform was not ceramic-coated but did not wear excessively and could be used on a large number of extrusions. The ceramic die was coated with .005 inches to .010 inches of ZrO_2 applied with a plasma arc gun. Initially, the ceramic coating was approximately .015 inches thick but was ground to obtain the proper thickness and smoothness.

The billet container, die holder, and back-up tooling was made from H-13 type tool steel hardened to 47 - 50 Rc. Punches have been made from several types of tool steels, H-13, S-5, H1-Shock 60, and M-2, with a hardness range of 53 Rc to 58 Rc. The higher hardness range is preferred because of the high stress encountered at impact, generally 200,000 psi to 250,000 psi.

5. Machine Set-Up

A schematic diagram of the tooling is shown in Figure 6. The punch is movable and is electrically operated. It is moved to the left (Figure 6) to allow the billet to be inserted and is then moved back to the center for extruding. This movement is very rapid and does not cause greater than a one-second delay in the extrusion procedure. The advantages of and the contribution of the "sliding punch" tooling, which was designed to lower extrusion velocities and make longer extrusions, have been described in the previous Technical Progress Report under this contract.

B. Extrusion Trials

1. First Trial

Four extrusions were made on the first trials. Originally, nine extrusions had been planned, but the dies were not properly coated and the extrusions were coming out with deep scratches.

The dies were made with a .070-inch slot to allow for a .002 inch molybdenum undercoat and an .008 inch ceramic coating on each side, resulting in a .050 inch final dimension. The undercoating on this set of dies varied from .002 inches to .010 inches. This did not allow a sufficient ceramic coating after sizing (none in some cases). In the bare and thin spots galling took place. In Figure 8, Ti-6Al-4V extrusion No. 516, is an example of an extrusion made with this set of dies. The nose of the extrusion has a good surface (60-70 RMS), but it gradually worsens and the deep scratches at the tail end yield a surface finish of 200 RMS. The steel extrusion had a similar surface from nose to tail. The extrusions made on the first trial are shown in Figure 7 and the die in Figure 9.

2. Second Trial

Eleven extrusions were made in the second trials, five Ti-6Al-4V, three AISI 4340, and three 304 stainless steel. The dies used for the first trials were sand blasted and recoated and used for these trials.

The extrusions made in these trials are shown in Figures 10 and 11 and a close-up of the surface finish of several of the extrusions is shown in Figures 12 and 13.

These trials went very well. The extrusions, with one exception, had good surfaces and very little dimensional variation along the length. The one extrusion that was

not good was a case of die failure. The ceramic coating broke off the die on one side of the stem and this surface was bad. On this extrusion the rest of the surfaces were good. This type of die failure is rare and is the first experienced in the last 9 months.

No braking device of any type was used. The extrusions are incomplete, that is, a small butt is left in the die which holds the extrusion in place. This butt is very small, usually a cubic inch or less and would not substantially add to the length of the extrusion if it were extruded. Part of it would form the tail which is usually hollow and would have to be cropped anyway. Pictures of the butts of the extrusions made in the second trial are shown in Figure 14.

LIST OF EXTRUSIONS MADE ON MODEL 1810 DYNAPAK

Ext. No.	Alloy	Red. Ratio	Fire Pressure (psi)	Ram back Pressure (psi)	Stroke Length	Temp. °F	Vol. Ext. (in.) ³	Ext. Lgth. (in.)	Remarks
514	Ti-6Al-4V	19.1	1800	150	10.8	1825	12.4	96	Defective die
515	Ti-6Al-4V	18.5	1810	150	10.8	1825	14.3	108	Defective die
516	Ti-6Al-4V	19.7	1800	150	10.8	1825	13.3	107	Defective die
517	4340	17.0	1800	150	10.8	2150	12.1	90	Defective die
518	Ti-6Al-4V	17.3	1830	140	11.6	1825	19.9	126	Good surface
519	Ti-6Al-4V	17.5	1800	150	11.6	1825	16.6	124	Good surface
520	Ti-6Al-4V	17.1	1850	140	10.9	1825	19.4	113	Good surface
521	Ti-6Al-4V	17.3	1850	140	10	1825	19.2	132	Good surface
522	Ti-6Al-4V	17.6	1850	140	10	1825	20.1	132	Good surface
523	304 s.s.	15.4	1950	160	10	2150	13.8	96	Good surface
524	304 s.s.	15.2	2000	160	10	2150	17.2	106	Good surface
525	4340	15.6	1990	160	10	2150	17.4	130	Good surface
526	4340	14.6	1925	160	10	2150	16.4	106	Good surface
527	4340	14.6	1900	170	10	2150	17.7	104	Good surface
528	304 s.s.	14.8	1925	160	10	2150	16.1	102	Good surface

Billets 514 through 517 were 1-3/4" dia. x 8-1/2" long
 Billets 518 through 522 were 1-3/4" dia. x 9" long
 Billets 523 through 528 were 1.645" dia. x 9-1/4" long

Table 1 - List of high velocity extrusions made on 1810 Model Dynapak machine.



FIGURE 2 - General view of Model 1810 Dynapak Machine. Upper and lower weights are on the right with two of the tie rods. Salt bath is visible in center and the induction heating facilities on the left.

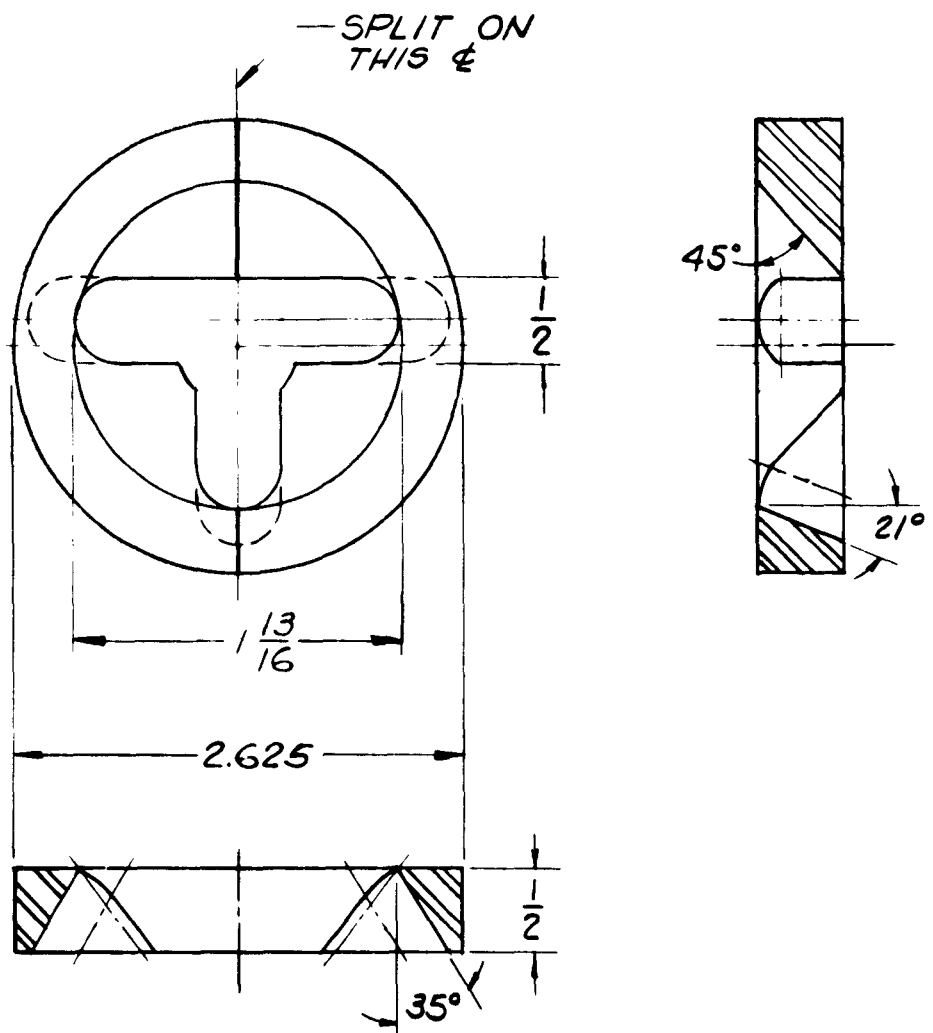


FIGURE 4 - Drawing of preform inserts. The billet shape is changed from a 1-3/4-inch diameter round to a 2-1/2 inch by 1-1/4 inch by 1/2 inch Tee configuration as it goes through the preform. Photograph of preform inserts and container are shown in Figure 5.

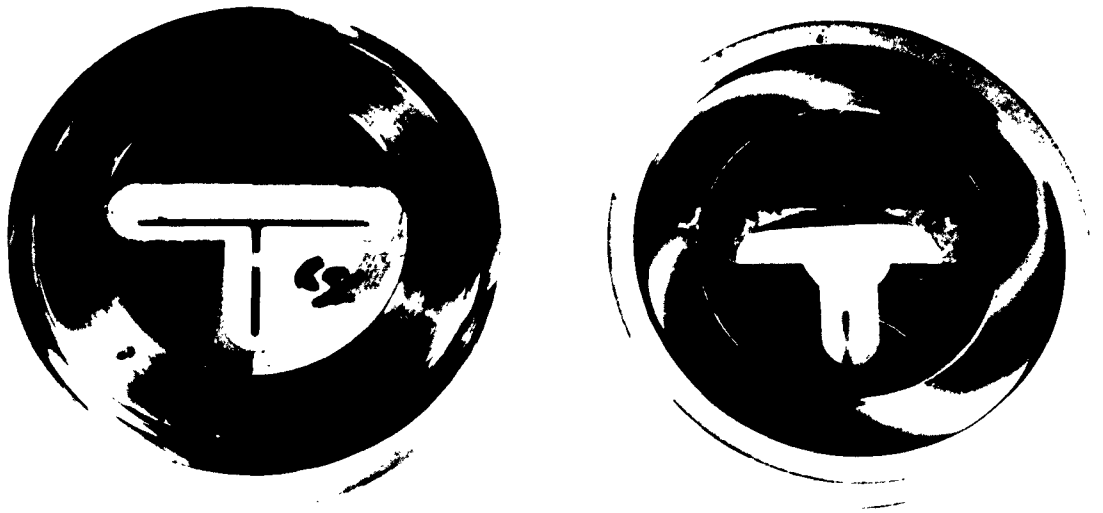


FIGURE 5 - Left - Three piece die and holder. Ceramic coated entry angle extends down to radius at 45° angle. The land is also ceramic coated and is 1/4 inch long. Right - Preform die is shown from bottom side. A round billet, 1-3/4" diameter, enters top of preform and is shaped and expanded to a 2 inch by 1 inch by 1/2 inch Tee. The Tee is then extruded as it goes through ceramic coated die.

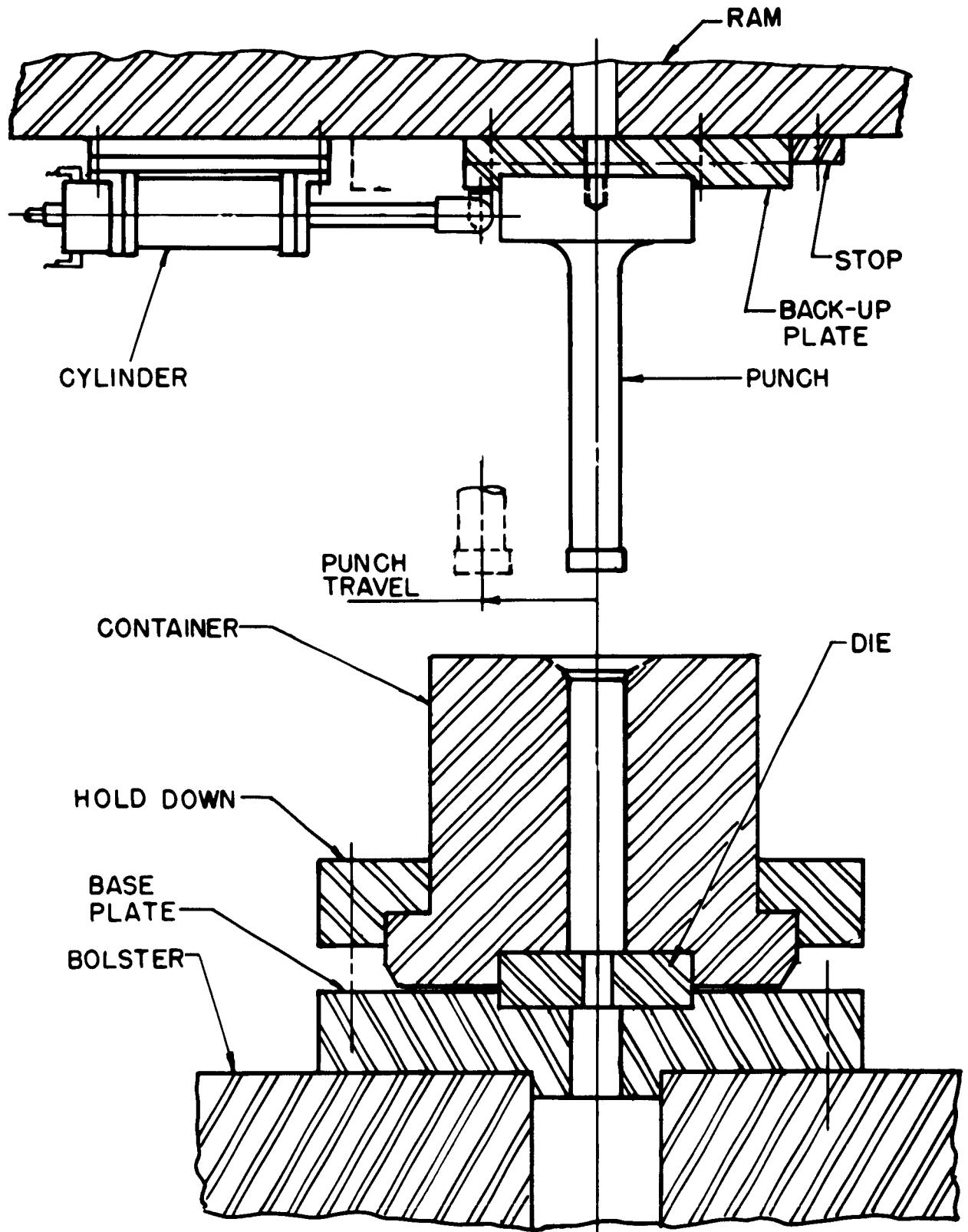


FIGURE 6 - Schematic diagram of 1-3/4 inch diameter tooling as seen from the side. Punch moves out of position to the left to permit insertion of billet into the container. The air cylinder at top left is electrically operated.



FIGURE 7 - Extrusions made on first extrusion trials of last quarter. These extrusions were unacceptable because of poor surface quality, see Figure 8. The extrusions from top to bottom are, No. 514, Ti-6Al-4V; No. 515, Ti-6Al-4V; No. 516, Ti-6Al-4V; and No. 517, AISI 4340.



FIGURE 8 - View of extrusion surface at nose and tail of extrusion No. 516. Surface finish is 70 RMS in nose area and 200 RMS in tail area. This large variation was the result of thin spots in the ceramic coating which caused galling near the tail end.

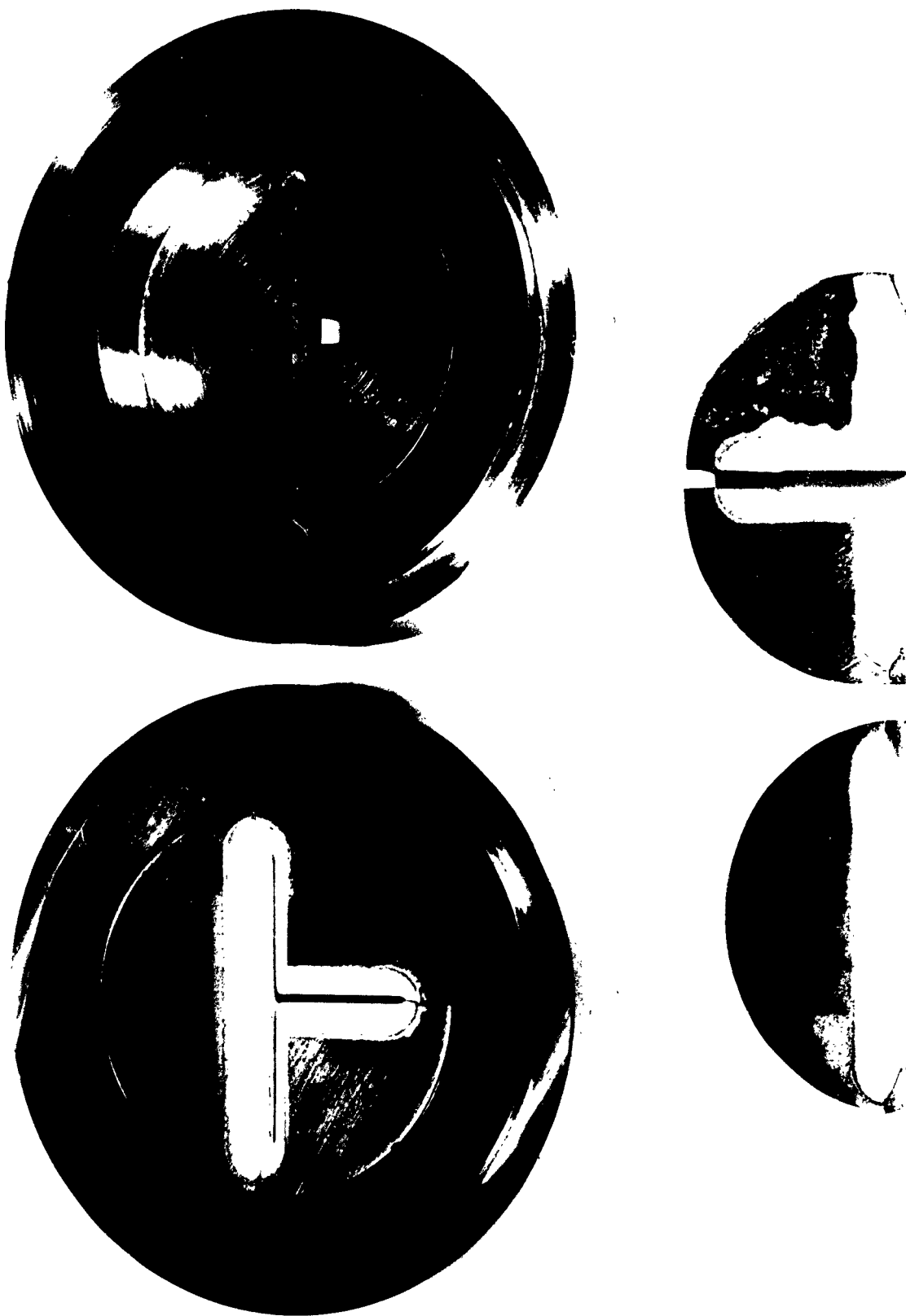


FIGURE 9 - View of die inserts and container. Upper left - inserts and container are assembled. Bottom - view of ceramic coating on the entrance angle and land. Notice the dark areas on land at bottom right. In these areas ceramic was ground off when die was sized.

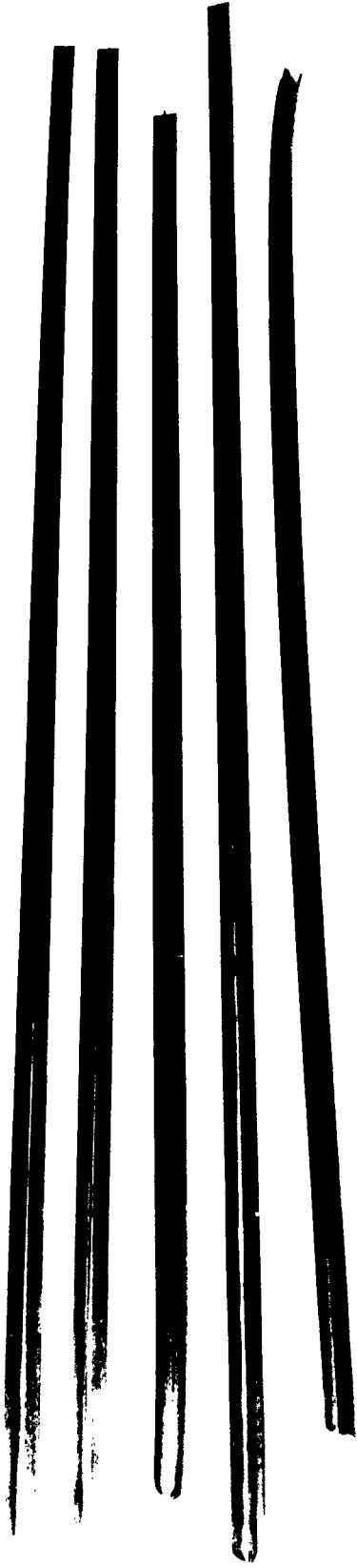


FIGURE 10 - Ti-6Al-4V alloy extrusions made on second extrusion trials. From top to bottom. No. 518. 126 inches; No. 519, 124 inches; No. 520, 113 inches; No. 521, 132 inches; No. 522, 132 inches.



FIGURE 11 - Steel extrusions made on second extrusion trials. From top to bottom, No. 523, 304 stainless steel, 96 inches; No. 524, 304 stainless steel, 106 inches; No. 528, 304 stainless steel, 102 inches; No. 525, AISI 4340, 130 inches; No. 526, AISI 4340, 106 inches; No. 527, AISI 4340, 104 inches.

V. RESULTS

The general appearance of the extrusions after sand blasting was good. Although they had not been straightened, they were relatively straight with little bow and camber, on the order of 1/2"-1" in 10 feet. The twist varied from several degrees up to 90 degrees.

Surface finish was very good on all the Ti-6Al-4V alloy extrusions. All the extrusions measured 60 RMS - 85 RMS, see Table 2, with an average of 70 RMS. The surface finish of the tail section was generally only 5 RMS to 10 RMS rougher than the nose indicating that there is no appreciable pickup on the die and very little die wear. The steel extrusions were not generally as good although two of these averaged 70 RMS and the other two, 100 RMS and 120 RMS. The extrusion, No. 527, which had the 120 RMS, had visual scratches from nose to tail which indicated that the die coating chipped or was scratched when the extrusion broke through the opening. In the past (and as reported in Interim Technical Progress Report No. 9) the surfaces of all three materials have been similar in smoothness.

The extrusions made on these trials were 8 - 11 feet long. The Ti-6Al-4V alloy extrusions averaged 10 feet and the steel extrusions 9 feet. Two of the stainless steel extrusions, 323 and 324, were severely distorted when they were sandblasted and will have to be straightened before measurements can be taken. The other stainless steel received a lighter sandblast and did not distort.

Dimensions of the die taken prior to extruding and the dimensions of the nose section of the extrusion are compared in Table 3. The general trend was for the extrusion to be approximately .03 to .04 inches smaller than the die in the 2-inch flange dimension and .01 to .02 inches smaller in the 1-inch stem dimension. Approximately one-half of this size change can be attributed to thermal contraction. The balance of the size change was probably due to elastic springback. During the extrusion period, the material is forced out to the die extremities under a severe compressive stress. However, once the material is through the die, this stress is relieved and the extrusion is free to elastically contract. Once made, the extrusion undergoes relatively high tensile forces due to the inertial forces in the extrusion. The tensile force would not affect these dimensions, however, unless they are sufficiently high to plastically deform the extrusion.

The thickness dimension of the stem and the flanges were usually larger than the die measurements. On two of the five Ti-6Al-4V extrusions the dimensions of the extrusions were several mills smaller than the die dimension. On the balance of the extrusions, including the AISI 4340 and 304 stainless steel, the extrusion dimensions were larger than the die dimension. This is in contrast to the length dimensions of the stem and flange which were generally smaller. Most of this increase can be attributed to die movement, that is movement of the inserts within their container. The insert and container were made in pairs with a "no-clearance" fit but after a number of hits this appeared to loosen allowing the dies to spread during the extrusion. With a shrink fit between inserts and container,

it is felt that the extrusion would nominally be .001 to .002 inches smaller than the die measurement.

It is recommended that the dimensions of future dies be made 2% larger than the desired extrusion dimensions to allow for contraction and that the inserts and container have an interference fit in order to hold the inserts firmly in place.

In a typical extrusion, dimensions of the flange and stem thickness varied only .002 -.003 inches over the length of the extrusion, the thinnest sections being near the tail. The height of the stem(which is nominally 1 inch) varied a maximum of .02 inches except in the 11-foot AISI 4340 extrusion, No. 525, which shows definite signs of necking. On this extrusion, the stem varied from .99 inches at the nose to .92 inches near the tail. The dimension of the width of the 2-inch flange had proportionally larger variation from nose to tail than any of the other dimensions. This dimension varied from .01 inches to .12 inches, with the smaller dimensions near the tail end. This reduction in size is probably due to necking but the other dimensions did not indicate a proportionate amount of necking. The dimensions of the as-extruded and sandblasted extrusions are listed in Tables 4-13.

A measurement of the radius at the intersection of the stem and flange was made on eight angles with an optical comparator. They were, .015, .015, .020, .025, .010, .010 and .010. These measurements are a good indication of the radii that can be obtained with this process. In the normal extrusion practice, radii of corners are conventionally .125 inches.



**SURFACE FINISH
RMS**

Ext. No.	Location	A	B	C	D	E	Ave.
518	Nose Tail	65- 75 75- 85	60- 65 75- 85	55- 65 65- 75	55- 65 80- 85	70- 80 80- 85	70
519	Nose Tail	65- 75 70- 80	60- 65 65- 70	55- 65 60- 70	55- 65 60- 70	60- 65 60- 65	65
520	Nose Tail	65- 70 75- 85	70- 80 60- 60	55- 60 90-100	65- 70 70- 75	Broken Die	70
521	Nose Tail	60- 70 70- 80	70- 70 70- 70	70- 70 60- 70	60- 60 80- 80	65- 70 70- 80	70
525	Nose Tail	65- 70 65- 70	70- 75 65- 70	80- 90 70- 80	55- 60 75- 80	65- 70 80- 90	70
526	Nose Tail	100-125 100-125	70- 80 90-105	80- 90 100-125	90- 90 100-110	80- 90 100-125	100
527	Nose Tail	125-140 100-120	100-125 100-115	125-135 125-140	125-130 140-150	100 115-125	120
528	Nose Tail	70- 80 70- 75	65- 70 60- 65	70- 80 65- 70	70- 80 65- 70	70- 75 65- 70	70

Table 2 - Surface finish measurements of high velocity extrusions made in second trials

DIMENSIONS OF TEE SECTION

<u>Die Ident.</u>	<u>A</u>	<u>B</u>	<u>C</u>	<u>D</u>	<u>E</u>	<u>Extrusion No. and Material</u>
1	2.00	1.03	0.050	0.050	0.050	518-T1-6Al-4V
1A	1.96	0.99	.047	.047	.045	
2	2.01	1.02	0.050	0.050	0.050	521-T1-6Al-4V
2A	1.97	0.99	.047	.050	.047	
3	1.99	1.03	0.050	0.049	0.049	523-304 s.s.
3A	1.96	1.02	.050	.052	.052	
4	2.01	1.03	0.050	0.054	0.052	526-4340
4A	1.99	1.01	.052	.055	.053	
5	2.05	1.03	0.049	0.050	0.052	524-304 s.s.
5A	2.02	1.00	.052	.060	.064	
6	1.99	1.01	0.049	0.049	0.050	525-4340
6A	1.96	.99	.049	.050	.050	
7	1.99	1.00	0.050	0.050	0.050	519-T1-6Al-4V
7A	1.98	1.02	.053	.050	.053	
8	2.04	1.05	0.050	0.049	0.050	520-T1-6Al-4V
8A	2.01	1.01	-----	.050	.052	
9	2.00	1.00	0.050	0.049	0.049	522-T1-6Al-4V
9A		Not measured				
10	2.00	1.00	0.053	0.053	.053	527-4340
10A	1.99	1.00	.057	.061	.061	
11	2.00	0.98	0.053	0.053	0.053	528-304 s.s.
11A	2.00	.98	.054	.057	.060	

1 - Dimensions of die prior to extrusion

1A - Dimensions of nose section of extruded section

Table 3 - Comparison of die dimensions and dimensions of extrusions

EXTRUSION DIMENSIONS

Material: T1-6Al-4V No.: 519 Length: 124"

<u>Loc. of Measurements</u>	<u>Width</u>	<u>Height</u>	<u>Stem</u>	<u>Right Flange</u>	<u>Left Flange</u>
Nose	1.98	1.02	.050	.051	.053
12"	1.98	1.02	.051	.050	.053
24"	1.97	1.02	.049	.051	.053
36"	1.94	1.02	.050	.050	.054
48"	1.92	1.01	.050	.049	.053
60"	1.90	1.02	.050	.048	.053
72"	1.90	1.02	.049	.049	.053
84"	1.90	1.02	.049	.048	.053
96"	1.90	1.01	.051	.048	.053
108"	1.90	1.01	.051	.049	.053
120"	1.90	1.02	.052	.050	.054
132"					
Die dimensions	1.99	1.00	.050	.050	.050

Table 4A - Dimensions of extrusion No. 519

EXTRUSION DIMENSIONS

Material: Ti-6Al-4V No.: 520 Length: 113"

<u>Loc. of Measurements</u>	<u>Width</u>	<u>Height</u>	<u>Stem</u>	<u>Right Flange</u>	<u>Left Flange</u>
Nose	2.02	1.01		.052	.051
12"	2.01	1.01		.053	.051
24"	2.01	1.01	Die Washed	.053	.052
36"	2.00	1.01		.053	.052
48"	2.00	1.01		.053	.053
60"	1.98	1.01		.054	.053
72"	1.97	1.01		.054	.053
84"	1.96	1.01		.053	.052
96"	1.96	1.01		.055	.052
108"	1.90	1.01		.054	.052
120"					
132"					
Die dimensions	2.04	1.05	.050	.049	.050

Table 4B - Dimensions of extrusion No. 520

EXTRUSION DIMENSIONS

Material: Ti-6Al-4V No.: 521 Length: 132"

<u>Loc. of Measurements</u>	<u>Width</u>	<u>Height</u>	<u>Stem</u>	<u>Right Flange</u>	<u>Left Flange</u>
Nose	1.98	.99	.047	.050	.048
12"	1.97	.99	.048	.050	.047
24"	1.97	.99	.049	.049	.048
36"	1.96	.99	.048	.050	.048
48"	1.94	.99	.049	.049	.047
60"	1.93	.99	.050	.049	.048
72"	1.92	.99	.050	.048	.048
84"	1.93	.99	.051	.048	.048
96"	1.95	.99	.051	.046	.048
108"	1.95	.98	.051	.044	.046
120"	1.95	.98	.049	.041	.045
132"	1.96	.99	.051	.047	.046
Die dimensions	2.01	1.02	.050	.050	.050

Table 4C - Dimensions of extrusion No. 521

EXTRUSION DIMENSIONS

Material: 304 s.s. No.: 523 Length: 96 "

<u>Loc. of Measurements</u>	<u>Width</u>	<u>Height</u>	<u>Stem</u>	<u>Right Flange</u>	<u>Left Flange</u>
Nose	1.96	1.03	.051	.053	.052
12"	1.96	1.02	.050	.052	.052
24"	1.96	1.02	.050	.052	.052
36"	1.96	1.02	.050	.052	.052
48"	1.95	1.02	.050	.052	.053
60"	1.95	1.02	.049	.051	.052
72"	1.95	1.01	.050	.051	.052
84"	1.95	1.01	.050	.051	.052
96"	1.95	1.01	.050	.051	.051
108"					
120"					
132"					
Die dimensions	1.99	1.03	.050	.049	.049

Table 4D - Dimensions of extrusion No. 523

EXTRUSION DIMENSIONS

Material: 304 s.s. No.: 524 Length: 105"

<u>Loc. of Measurements</u>	<u>Width</u>	<u>Height</u>	<u>Stem</u>	<u>Right Flange</u>	<u>Left Flange</u>
Nose	2.01	1.00	.053	.064	.061
12"	2.02	1.00	.052	.064	.060
24"	2.02	1.00	.052	.064	.059
36"	2.02	1.00	.052	.064	.059
48"	2.01	1.00	.052	.064	.058
60"	2.01	.99	.051	.063	.057
72"	2.00	.99	.051	.063	.057
84"	1.99	.98	.051	.062	.058
96"	1.96	.98	.051	.061	.058
108"	1.99	.99	.051	.060	.057
120"					
132"					
Die dimensions	2.04	1.02	.049	.052	.050

Table 4E - Dimensions of extrusion No. 524

EXTRUSION DIMENSIONS

Material: AISI 4340 No.: 525 Length: 130"

<u>Loc. of Measurements</u>	<u>Width</u>	<u>Height</u>	<u>Stem</u>	<u>Right Flange</u>	<u>Left Flange</u>
Nose	1.95	.99	.050	.050	.050
12"	1.96	.99	.049	.050	.050
24"	1.96	.99	.049	.050	.050
36"	1.95	.98	.049	.050	.050
48"	1.95	.98	.048	.049	.050
60"	1.93	.97	.048	.049	.049
72"	1.91	.96	.047	.048	.048
84"	1.87	.95	.046	.047	.047
96"	1.84	.93	.045	.046	.046
108"	1.81	.92	.045	.045	.046
120"	1.81	.92	.045	.045	.046
132"	1.86	.96	.046	.046	.046
Die dimensions	1.99	1.01	.049	.049	.050

Table 4F - Dimensions of extrusion No. 525

EXTRUSION DIMENSIONS

Material: AISI 4340 No.: 526 Length: 106"

<u>Loc. of Measurements</u>	<u>Width</u>	<u>Height</u>	<u>Stem</u>	<u>Right Flange</u>	<u>Left Flange</u>
Nose	1.97	1.01	.053	.053	.055
12"	1.99	1.01	.052	.053	.055
24"	1.99	1.01	.052	.052	.055
36"	1.99	1.01	.052	.053	.054
48"	1.99	1.01	.052	.053	.054
60"	1.97	1.01	.052	.052	.054
72"	1.96	1.00	.051	.052	.054
84"	1.94	1.00	.051	.051	.053
96"	1.93	1.00	.051	.050	.053
108"	1.92	1.00	.050	.050	.051
120"					
132"					
Die dimensions	2.01	1.03	.050	.052	.054

Table 4G - Dimensions of extrusion No. 526

EXTRUSION DIMENSIONS

Material: AISI 4340 No.: 527 Length: 104"

<u>Loc. of Measurements</u>	<u>Width</u>	<u>Height</u>	<u>Stem</u>	<u>Right Flange</u>	<u>Left Flange</u>
Nose	1.97	1.00	.057	.061	.061
12"	1.99	1.00	.057	.061	.061
24"	1.99	1.00	.057	.061	.061
36"	1.99	1.00	.056	.061	.060
48"	1.99	1.00	.056	.061	.060
60"	1.97	1.00	.055	.060	.060
72"	1.96	.99	.056	.060	.059
84"	1.95	.99	.056	.060	.059
96"	1.94	.99	.056	.059	.059
108"	1.95	1.00	.056	.059	.058
120"					
132"					
Die dimensions	2.00	1.00	.053	.053	.053

Table 4H - Dimensions of extrusion No. 527

EXTRUSION DIMENSIONS

Material: 304 s.s. No.: 528 Length: 101"

<u>Loc. of Measurements</u>	<u>Width</u>	<u>Height</u>	<u>Stem</u>	<u>Right Flange</u>	<u>Left Flange</u>
Nose	2.00	.98	.054	.060	.057
12"	2.00	.98	.054	.060	.057
24"	2.00	.98	.054	.059	.057
36"	2.00	.98	.054	.059	.057
48"	2.00	.98	.054	.059	.056
60"	2.00	.97	.053	.059	.056
72"	2.00	.97	.053	.059	.056
84"	2.00	.97	.053	.059	.056
96"	1.99	.97	.053	.058	.056
108"	1.98	.97	.053	.058	.055
120"					
132"					
Die dimensions	2.00	.98	.053	.053	.053

Table 4I - Dimensions of extrusion No. 528

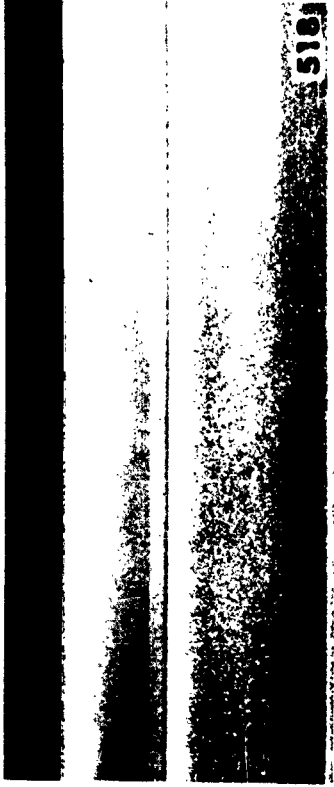


FIGURE 12 - View of Ti-6Al-4V alloy extrusion Nos. 518 and 519. There is no appreciable difference in the surface finish of the nose section at the right and the tail at the left.

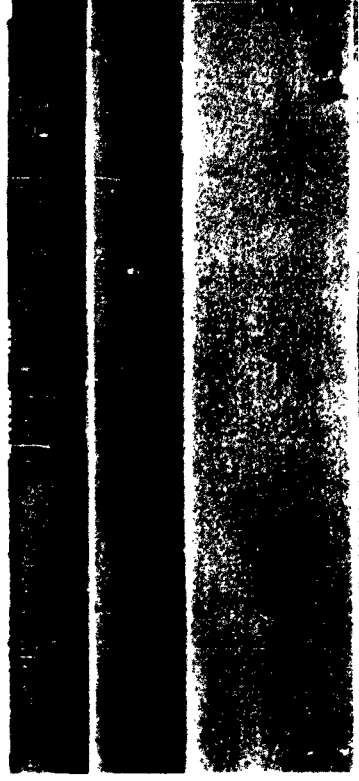
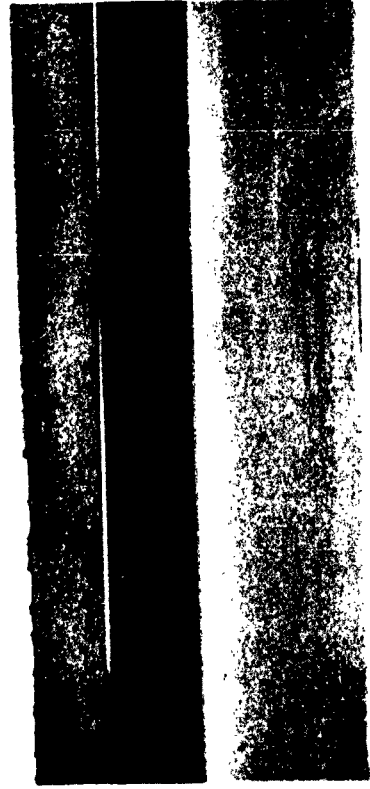
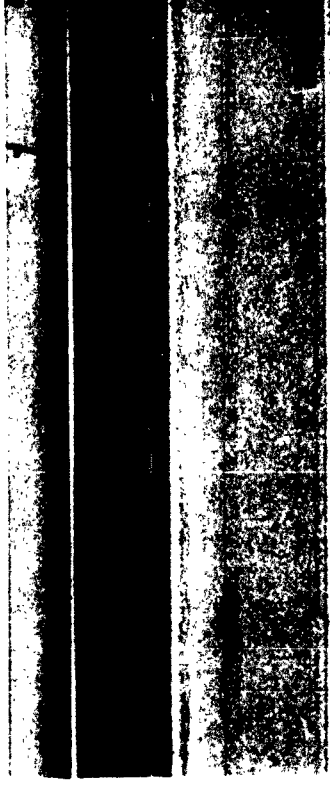
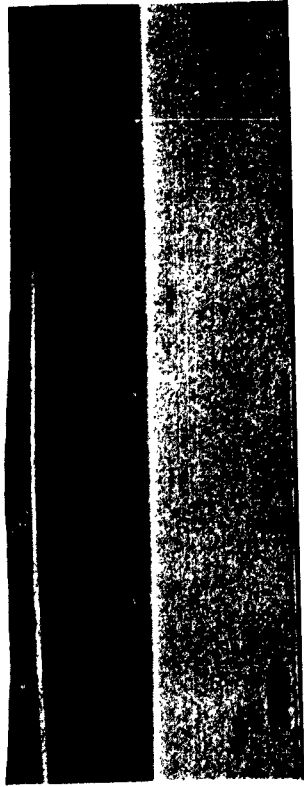


FIGURE 13 - View of steel extrusion Nos. 525 and 528. Extrusion No. 525 at top is AISI 4340, No. 528 at the bottom is 304 stainless steel. Surface finish is 70 RMS on nose and tail of both extrusions.

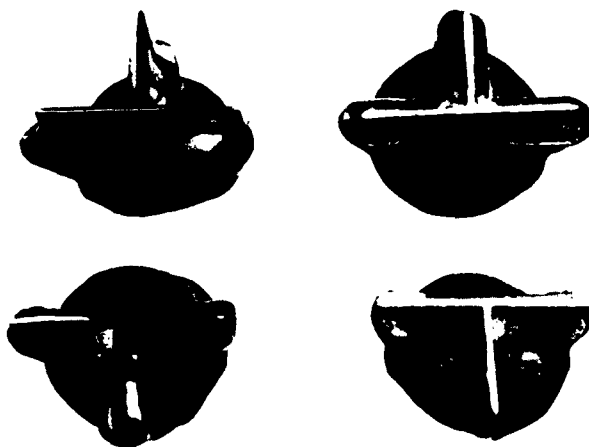


FIGURE 14a - Extrusion stubs from Ti-6Al-4V extrusions of second trials. Stubs normally contain 1 cubic inch of material.



FIGURE 14b - Extrusion stubs from steel extrusions of second trials. These stubs average 2 cubic inches of material.

VI. WORK FOR NEXT REPORTING PERIOD

The original intention to begin Phase III in the last reporting period was postponed to permit demonstrating the repeatability and consistency with which Ti-6Al-4V, AISI 4340 and 304 stainless steel could be made to the requirements of the contract. This having been done, Phase III will begin in the next quarter.

The objective of Phase III will be the development of a process for the extrusion of B-66 columbium alloy and TZM molybdenum-base alloy into a 2 inch by 1 inch by .050 inch Tee configuration. The problems associated with attaining these objectives will be divided into several separate but related working areas. First, there will be defined the process parameters required to extrude the volume of metal of each alloy, 18 cubic inches, equivalent to 10 feet of the reference section. These parameters will then be modified as necessary to produce the maximum length of extrusion having full aircraft quality and meeting all the dimensional and surface requirements. Second, a straightening process will be developed. This will include any necessary preheat treatment or post heat treatment of the straightened material in addition to the required warm or hot straightening procedure. Third, the extrusions will be evaluated for microstructure and mechanical properties.

Work in the next reporting period will be directed primarily at the investigation of the extrusion process parameters. The heating requirements, lubrication, reduction ratio and extrusion temperature will be determined to extrude 18 cubic inches of each material. A

correlation will be made between extrusion temperature and surface finish, extrusion pressure and microstructure. Selected extrusions will be heat treated and tested to obtain preliminary mechanical properties. These investigations will be conducted on both the 1210 Dynapak and 1810 Dynapak machine.

Contract No. AF 33(600)-41948
Project No. 7-882

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